NASA/TM—2016-219378

An Overview of Power, Energy Storage, and Conversion Efforts for 2014 SBIR Phases I and II

Hung D. Nguyen and Gynelle C. Steele
Glenn Research Center, Cleveland, Ohio

October 2016

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program plays a key part in helping NASA maintain this important role.

The NASA STI Program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI Program provides access to the NASA Technical Report Server—Registered (NTRS Reg) and NASA Technical Report Server—Public (NTRS) thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counter-part of peer-reviewed formal professional papers, but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., "quick-release" reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at http://www.sti.nasa.gov

- E-mail your question to help@sti.nasa.gov

- Fax your question to the NASA STI Information Desk at 757-864-6500

- Telephone the NASA STI Information Desk at 757-864-9658

- Write to:
  NASA STI Program
  Mail Stop 148
  NASA Langley Research Center
  Hampton, VA 23681-2199

NASA/TM—2016-219378

An Overview of Power, Energy Storage, and Conversion Efforts for 2014 SBIR Phases I and II

Hung D. Nguyen and Gynelle C. Steele
Glenn Research Center, Cleveland, Ohio

National Aeronautics and
Space Administration

Glenn Research Center
Cleveland, Ohio 44135

October 2016

Level of Review: This material has been technically reviewed by technical management.

Available from

NASA STI Program
Mail Stop 148
NASA Langley Research Center
Hampton, VA 23681-2199

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
703-605-6000

This report is available in electronic form at http://www.sti.nasa.gov/ and http://ntrs.nasa.gov/

Contents

An Overview of Power, Energy Storage, and Conversion Efforts for 2014 SBIR Phases I and II

Hung D. Nguyen and Gynelle C. Steele
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Abstract

Technological innovation is the overall focus of NASA’s Small Business Innovation Research (SBIR) program. The program invests in the development of innovative concepts and technologies to help NASA’s mission directorates address critical research and development needs for agency projects.

NASA’s Small Business Innovation Research (SBIR) program focuses on technological innovation by investing in development of innovative concepts and technologies to help NASA mission directorates address critical research needs for Agency programs.

This report highlights 15 of the innovative SBIR 2014 Phase I and II projects that focus on one of NASA Glenn Research Center’s six core competencies—Power, Energy Storage and Conversion. The technologies cover a wide spectrum of applications such as high-radiation-tolerant ceramic voltage isolators, development of hermetic sealing glasses for solid oxide fuel cells, rechargeable lithium metal cells, high-efficiency direct methane solid oxide fuel cell systems, Li metal protection for high-energy space batteries, isolated bidirectional direct current converters for distributed battery energy applications, and high-efficiency rad-hard ultrathin Si photovoltaic cell technology for space. Each article describes an innovation and technical objective and highlights NASA commercial and industrial applications.

This report provides an opportunity for NASA engineers, researchers, and program managers to learn how NASA SBIR technologies could help their programs and projects, and lead to collaborations and partnerships between the small SBIR companies and NASA that would benefit both.

High Radiation Tolerant Ceramic Voltage Isolator (Non-Optical Gate Driver)—Phase I

QorTek, Inc.

Abstract

The goal of the Phase I effort was to design, develop and demonstrate a novel solid-state ceramic-based voltage isolator and demonstrate its potential to provide a highly radiation tolerant digital voltage isolation solution applicable to a wide range of NASA mission requirements. The design and demonstration success has shown a completely new, very rad hard, gate drive technology solution with many advantages and benefits across the entire spectrum of NASA missions and commercial applications. The Phase I design goals were focused primarily on early COMSOL Multiphysics based Finite Element Analysis (FEA) of the proposed ceramic device, as well as electrical circuit design and SPICE modeling of a high-side MOSFET gate driver system incorporating the new ceramic isolator. This program exited having achieved its main Phase I objective of both designing and fabricating test article of this new technology of ceramic-based gate driver/isolator devices including electrical test characterization of their performance—which was excellent. The next step was to demonstrate an integrated electrical design targeted to provide a new isolated MOSFET gate driver capability. Through design, hardware functional testing and device characterization the Phase I showed that this new ceramic gate driver technology provides for a replacement for incumbent custom or COTS gate drivers or isolated digital transmission solutions that is not only size and performance comparable, but is now inherently very rad hard.

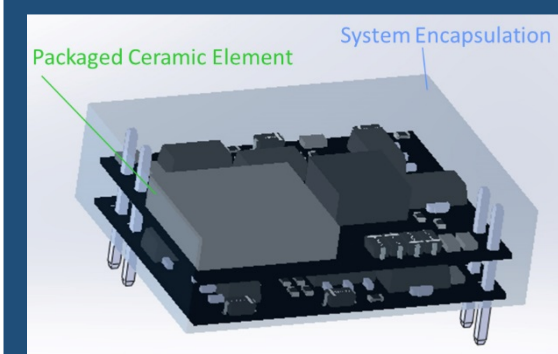
Applications

NASA

There are critical needs encompassing nearly every NASA mission that require (sometimes very) rad hard capable digital isolator/signal transmission and gate driver devices. These include deep space applications involving orbiters and landers that require data isolation circuits to block noise as well as level shifting interfaces for digital to analog formats. The technology would be greatly helpful to critical to Heliophysics and high-orbit Earth (MEO, GEO) mission needs where these platforms are now subject to higher levels of radiation exposure.

Commercialization

Commercial applications include systems involving error-free data transmission at high speed. Any system that presently relies on optocouplers could also greatly benefit from this new technology. These systems include industrial power supplies and regulation systems, electric motor control and drive systems, and instrumentation and medical systems. Another important application areas is in the emergence of Wide Band Gap based switching power supply design where goal is to exploit the high thermal capability of WBG power deices as to run at much higher operating temperatures. These new devices also provide for an ideal solution for high temperature operating gate drives for power topologies.



Firm Contact

Cathy Bower
cbrooke@qortek.com
1965 Lycoming Creek Road, Suite 205
Williamsport, PA 17701-1251
(570) 322-2700

Proposal number: 14-1 S3.03-9045

Development of Hermetic Sealing Glasses for Solid Oxide Fuel Cells—Phase I

MO-SCI Corporation

Abstract

Sealing glasses, either rigid glass-ceramics or viscous, non-crystallizing compositions, will be developed and sealing processes will be optimized based on NASA's solid oxide fuel cell (SOFC) designs. SOFC design constraints, including material selection and operational conditions, will guide compositional development, and then these new compositions will be used for long-term (>500 hr) material compatibility tests under SOFC operational conditions. Prototype seals will be produced and will be thermally cycled between room temperature and 850 °C to test the thermo-mechanical compatibility of the sealing materials with SOFC components. At the end of this Phase I project, sealing compositions and processes will be identified for SOFC applications identified by NASA.

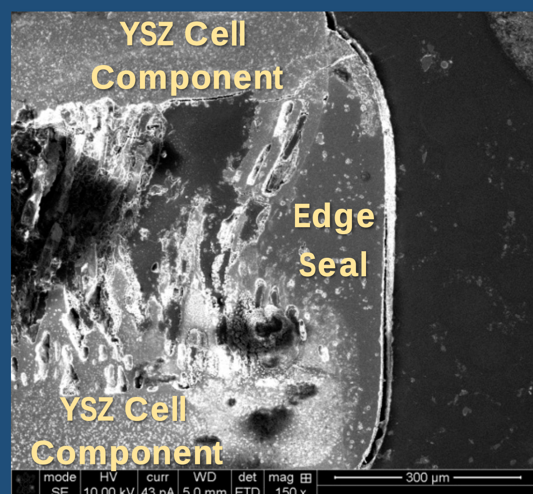
Applications

NASA

The long-term space exploration mission of NASA requires high-efficiency power systems to be used for the human exploration and operations in space. Solid oxide fuel cells (SOFCs) are of current interest because they can utilize methane and other fuels generated on-site at the Moon or Mars to produce electricity. Solid oxide electrolyzers (SOEs) are also of importance as a life support system because SOEs can generate oxygen by electrolyzing CO_2 available in space. Both SOFCs and SOEs are high-temperature systems and require robust seals that can prevent intermixing of air (oxygen) and fuel, remain inert in reducing and oxidizing environments while in contact with SOFC/SOE materials, and maintain their effectiveness through repeated thermal cycles. This SBIR program will provide new reliable, thermally stable, hermetic sealing materials critical for the development of SOFCs and SOEs.

Commercialization

This SBIR project will assist the nation's SOFCs program in meeting its cost and performance targets by ensuring that SOFC seals can achieve reliable operation over an extended operating life. The program will ultimately enable fuel cell-based near-zero emission coal plants with greatly reduced water requirements and the capability of capturing 97% or greater of carbon at costs not exceeding the typical cost of electricity available today. Achieving this goal will significantly impact the nation given the size of the market, expected growth in energy demand, and the age of the existing power plant fleet. It will also provide the technology base to enable grid-independent distributed generation applications.



Firm Contact

Ted E Day
tday@mo-sci.com
4040 Hy Point North
Rolla, MO 65401-8277
(573) 364-2338

Proposal number: 14-1 H8.01-9586

Rechargeable Lithium Metal Cell—Phase I

Physical Sciences, Inc.

Abstract

During Phase I, PSI demonstrated the ability to repeatedly construct Ah+ sized rechargeable lithium metal cells with energy densities 80% greater than achievable with standard components and techniques. On scale-up and production of 5 Ah cells these designs will enable cell level energy densities of >400 Wh/kg. This will extend the operating times of devices and provide the necessary energy and power to operate next generation devices and support future NASA missions. PSI's lithium metal cell design combines a proprietary high energy density cathode and novel cell construction and operating techniques to deliver these enhanced performance levels. PSI demonstrated the approach is compatible with multiple cathode materials, including developmental next generation materials that would increase the achievable cell energy density on their commercialization.

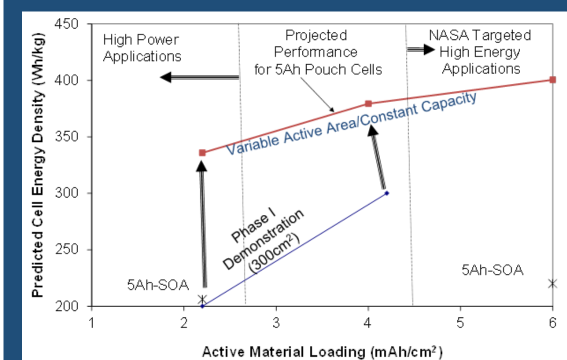
Applications

NASA

This cell technology could be utilized in all NASA battery applications. In particular the rechargeable lithium metal cell technology could be used in any mission or application that requires low mass and low volume. The absence of an intercalation component on the negative electrode allows for higher discharge rate capabilities. Applications include EVA suits, landers, rovers, habitats, vehicle power, and power for payloads.

Commercialization

The initial market for the proposed technology is military aerospace applications where space is limited and battery energy density is critical. In addition, the technology also would be well suited to powering microdevices, such as remote sensing devices, that would benefit from the increased runtimes and reduced battery size enabled by the increased battery energy density. The proposed technology could also be used in applications that need high power and energy, such as power sources for high energy laser systems. The higher energy and power densities offered are required to meet the weight requirements of this application. The system may also be used in emergency power generators and as a replacement for current power sources employing primary and thermal batteries.



Firm Contact

Christopher M. Lang
lang@psicorp.com
20 New England Business Center
Andover, MA 01810-1077
(978) 689-0003 Extension: 8125

Proposal number: 14-1 Z1.02-9269

Isolated Bidirectional DC Converters for Distributed Battery Energy Applications—Phase I

GridBridge, Inc.

Abstract

Power systems are the core heartbeat of any advanced vehicle. Reliability and flexibility of these systems are therefore of the highest priority. This Phase 1 project proposes a highly efficient and modular isolated bidirectional DC converter for battery energy applications. GridBridge is utilizing advanced DC converter topologies for modernization of the today's electrical distribution power grid and will translate work into high priority NASA power system applications, demonstrating transferability, robustness, and scalability. This bidirectional DC converter offers an extremely high power density and will utilize a novel hybrid resonance and PWM technique to achieve. It will also offer NASA the flexibility for many power system topologies, including: distributing large single cells throughout the vehicle, use of smaller cells in a centralized location, or a combination banked smaller cells distributed throughout the system. This is accomplished through independent charging and discharging control of state-of-charge and state-of-health for each battery module, inherent active maximum current limit and short-circuit protection, and ease of module balancing.

Applications

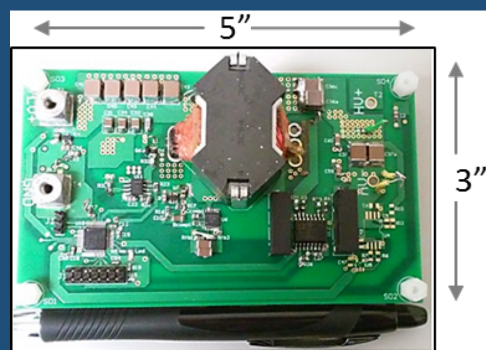
NASA

Highly efficient modular DC converters are coveted throughout numerous applications due to the increased flexibility and reliability they offer to the power system. In terms of flexibility, the modular DC converters offer the ability to design a centralized or decentralized power system topology. This is certainly relevant within electric propulsion systems of vehicles and is therefore a primary target application. The benefits related catastrophic containment and mass distribution can be analyzed, each benefiting from the availability of a modular DC converter. Additionally, cost avoidance is important. Many redundant power systems can be avoided through the self-healing (rerouting) nature of battery strings incorporating modular DC converters. Additionally, each cell can be monitored independently, therefore eliminating much of the system monitoring that is currently required in electric propulsion and radioisotope applications.

The initial targeted customers are SMD's In-space Propulsion Technology and Radioisotope Power Systems programs. The modular approach and promise of scalability though means this technology could be adaptable and transferable to various space applications, including the Orion, Constellation, and many other programs.

Commercialization

Highly efficient modular DC converters can be utilized in numerous grid applications, including integration of solar, wind, electric vehicle charging, and energy storage.



Unoptimized prototype bidirectional DC Converter resulting from Phase 1 effort.

Firm Contact

Chad Eckhardt
chad@grid-bridge.com
130 Penmarc Drive, Suite 101
Raleigh, NC 27603
(919) 413-9898

Proposal number: 14-1 S3.03-9128

High Energy Density Lithium Battery System with an Integrated Low Cost Heater Sub-System for Missions on Titan—Phase I

American Energy Technologies Company

Abstract

This Phase I SBIR project became a joint development effort between AETC and Advanced Technology Laboratories of Lockheed Martin Corp., Eagan, MN. We sought to develop a 25 VDC Lithium/Carbon Monofluoride battery which is based on application of 32650 cylindrical cells. The intended application of battery shown is a principal power source in probes and landers on near-Earth asteroids. The battery is insulated from the exterior environment by an engineered gap which is filled with technical vacuum. Since the thermal transfer in vacuum is approaching zero, this battery is designed to withstand travel in space, while consuming greatly reduced amounts of external heat. The battery is heated in-situ by the Joule heat released from thermal losses of discharging cells and from the embedded resistive heaters. The latter are powered by a fraction of energy which is built into the battery module. The source of commercial opportunity with this development is to address concerns associated with the application of Radioactive Heating Units (RHU) as heat sources on landers. According to the DOE in 2005 the U.S. government owned 87 pounds of $^{238}PuO_2$, of which roughly 36 pounds remain earmarked for NASA. A tangible opportunity exists with AETC's 500+Wh/kg Li/CF_x cell-based battery to dedicate a portion of its energy for the operation of a built-in heater subsystem. As a result, in parachutable probes where the battery occupies most of the system's volume, the number of RHUs could potentially be reduced in half.

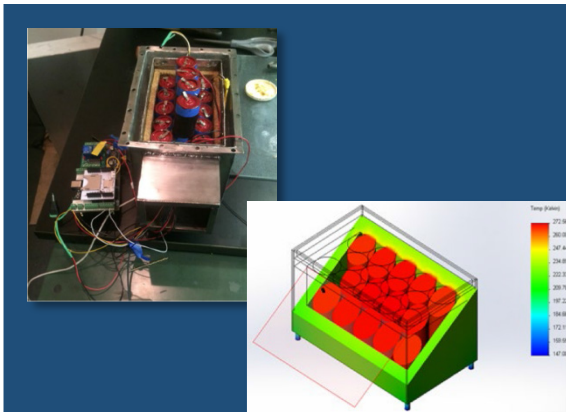
Applications

NASA

The proposed development of an ultra-high energy density, inherently safe and highly efficient advanced battery system is geared towards benefiting several groups of applications within NASA. They include next generation safe batteries for power systems on lunar rovers, ascent systems, EVA suits, re-entry vehicles, etc. Non-Government space programs (i.e., commercial space exploration) will also likely use the battery platform in order to replace banks of lithium-ion batteries on reentry vehicles.

Commercialization

Down-to-earth applications for this technology include: medical batteries; power sources for remote unmanned sensors; batteries for Army missions; consumer electronics; and in the PC computer world: CMOS backup battery; high-end computer redundant array of independent disks (RAID) disk controllers, etc.



Firm Contact

Igor V. Barsukov
IBarsukov@usaenergytech.com
220 W Campus Ct., Unit D
Arlington Heights, IL 60004
(847) 414-6788

Proposal number: 14-1 S3.03-9142

Fabrication of T-SOFC via Freeze Cast Methods for Space and Portable Applications—Phase I

Yanhai Power, LLC

Abstract

As NASA space missions become longer in duration the need for high efficiency power generator sets that can operate on NASA logistical fuel become critical. Historically NASA has used fuel cells as part of the energy solution. Space bound energy and power systems require rapid start and stop cycle times as well as high power densities. The high operational efficiency, coupled with the use of logistical fuel options make fuel cells vital to the extended future missions of NASA. Solid Oxide Fuel Cells (SOFCs) have been demonstrated on a variety of gaseous and liquid hydrocarbon fuels. Our team has successfully developed a freeze cast process to fabricate tubular SOFCs and is working on stack and system development. With conventional tubular SOFCs, the power systems are capable of cycling from room temperature to 700 °C and full power in less than 15 minutes; the stacks have been cycled more than 250 times and single cells have demonstrated life times greater than 2000 hr. Coupling the freeze cast microstructure with the rapid cycling and portability of the tubular systems will lead to a high power density robust SOFC system operating on methane and oxygen capable of space missions.

Applications

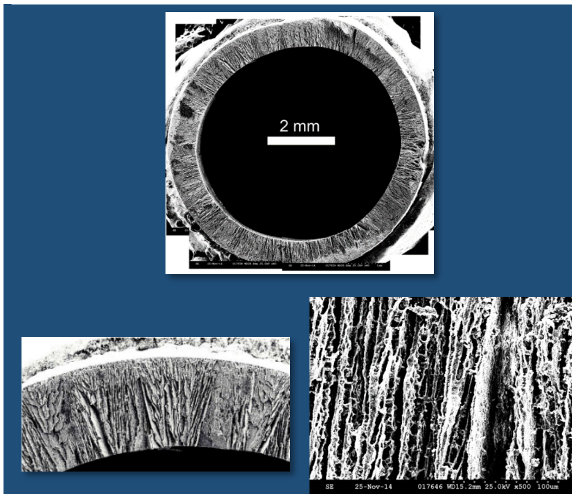
NASA

Specifically, cells developed during this program can be further used in the following systems:

- Energy storage and maintenance for the international space station
- High altitude balloons
- High altitude aircraft
- Energy storage for future missions and settlement on the Moon and Mars

Commercialization

This unique fuel cell microstructure can be leveraged across all SOFC developments, improving both system power density and reducing cost and used for electrolysis of water and or carbon dioxide leading to a host of applications such as: CO_2 conversion, Hydrogen or Oxygen production, and the production of metals from oxide salt mixtures.



Firm Contact

Tyler Tatum
ttatum@yanhaipower.com
7465 Valerie Lane
Hudson, OH 44236
(404) 783-0923

Proposal number: 14-1 H8.01-9741

High Performance Lithium Sulfur Battery With Novel Separator Membrane For Space Applications—Phase I

Bettergy Corp.

Abstract

For NASA's human and robotic mission, the battery with extremely high specific energy (>500 Wh/kg) and long cycle life are urgently sought after in order to reduce the payload weight. Current state-of-the-art lithium ion batteries, such as graphite/$LiCoO_2$ or graphite/$LiFePO_4$ systems, have limited specific energy to around 220 Wh/kg on the cell level. In order to meet the future NASA mission requirements, new out-of-box battery chemistries and components need to be developed. Driven by the strong market pull, Bettergy has invented a novel ion selective membrane that can be employed along with Li_2S based cathode material to develop the next generation lithium sulfur battery. This novel battery is expected to have 1) high specific energy (>500 Wh/kg); 2) long cycle life (> 1000 cycles); 3) long storage life and 4) great safety feature, which can meet the challenge requirements of the NASA mission.

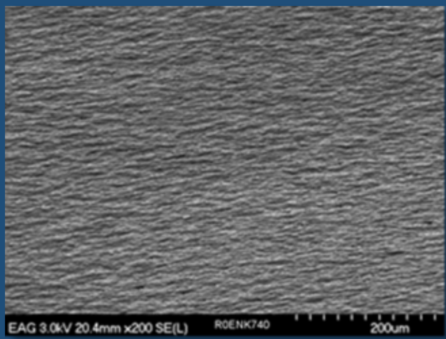
Applications

NASA

Advanced high energy battery systems are now sought for use in the future NASA human and robotic mission. Light weight and long life battery could substantially reduce the payload for the mission and extend the mission duration. This represents significant market opportunity.

Commercialization

Rechargeable lithium-ion batteries are now used extensively in a wide range of consumer applications where high energy densities and extended cycle life are required. Also, there is growing trend in using these batteries for EV, HEV and PHEV, as well as electric energy storage. The global market for these batteries is estimated to be US$18 billion in 2010 and is growing at double digit rate. It is expected this high energy density battery will capture certain market share in this commercial market.



Ion Selective Membrane for Li/S Battery

Firm Contact

Lin-Feng Li
linfengli@bettergy.com
8 John Walsh Blvd., Suite 321
Peekskill, NY 10566-5330
(914) 290-6293

Proposal number: 14-1 Z1.02-9604

Highly Conductive Polymer Electrolyte Impregnated 3d Li-Metal Negative Electrode—Phase I

Xerion Advanced Battery

Abstract

XABC (Xerion Advanced Battery Corp) proposes a novel anode with three unique features, each designed to 1) control or 2) prevent dendrite growth. The first feature is a 95% porous electrode architecture. This electrode is an open-cell, nanostructured conductive foam whose internal structures are conformally coated with lithium metal. The second feature is a five micron mask that, when applied to the surface of the 3d foam, prevents electrodeposition of lithium metal near the surface of the electrode, hence preventing growth of lithium dendrites near the surface. The third feature is a novel, highly conductive ionic fluid rigid-rod polymer composite expected to achieve a conductivity of 8.3×10^{-3} S/cm^2. XABC believes that the novel combination of these three unique features will enable the stable cycling of lithium metal in a secondary cell. For Phase I, XABC proposes to fabricate and test the effect of both the polymer and masked 3d foam on dendrite suppression. For Phase II, XABC proposes to fabricate fully functioning negative electrodes with the features above.

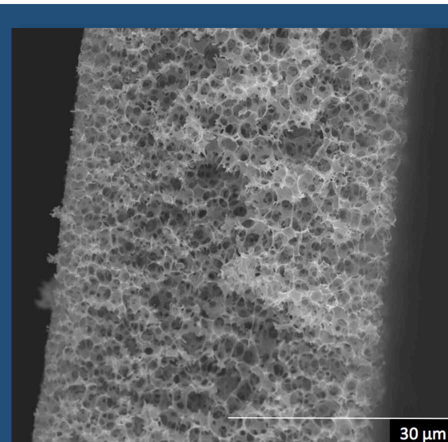
Applications

NASA

NASA is currently planning on deploying lithium ion batteries onto the ISS to replace its aging nickel-hydrogen cells (Clark 2013). The Hubble telescope also uses nickel-hydrogen cells. Li-ion batteries w/ 500 Wh/kg would increase lifetime, which would result in significant cost savings to due a reduction in space walks. Such a cell would also reduce operational risk when deployed on probes, rovers and the like.

Commercialization

There are many potential markets where XABC can have an impact, which include consumer electronics, server farms, power tools, grid backup, military, medical, robotics and others. XABC will focus on applications of high desirability in three of the many potential market segments: 1) Military, DoD and NASA applications where enhanced performance at a much lower weight is highly desirable. 2) Portable electronic devices especially in the rapidly growing mobility market for laptops, netbooks, tablets and phones. 3) Automotive application for electric, gasoline hybrid, and fuel cell hybrid vehicles.



Firm Contact

Justin Lenoff
j.lenoff@xerionbattery.com
60 Hazlewood Drive
Champaign, IL 61802-7460
(217) 265-5215

Proposal number: 14-1 Z1.02-9486

High-Efficiency Rad-Hard Ultra-Thin Si Photovoltaic Cell Technology for Space—Phase I

CFD Research Corporation

Abstract

In this project, we propose a novel, ultra-thin Si photovoltaic (PV) cell technology that combines enhanced light trapping and absorption due to nanostructured surfaces, separation of photogenerated carriers by carrier selective contacts, and increased carrier density due to multiple exciton generation. Such solar cells have the potential to achieve efficiencies of 40+%, while being radiation-hard, lightweight, flexible, and low–cost, due to the use of Si high volume fabrication processes.

In Phase I, CFDRC partnered with the Quantum Energy and Sustainable Solar Technologies (QESST) Engineering Research Center (ERC) center at Arizona State University to develop and demonstrate proof-of-concept of the nanostructured, ultra-thin Si photovoltaic cell technology. This effort included design, modeling, fabrication, and experimental characterization of an ultra-thin flexible Si based solar cell.

In Phase II, the physical mechanisms currently limiting light trapping, open-circuit voltage (Voc), and multiple exciton generation will be identified, and addressed. The ultra-thin rad-hard cell design will be optimized (for > 36% efficiency) and a solar cell will be fabricated and presented for testing.

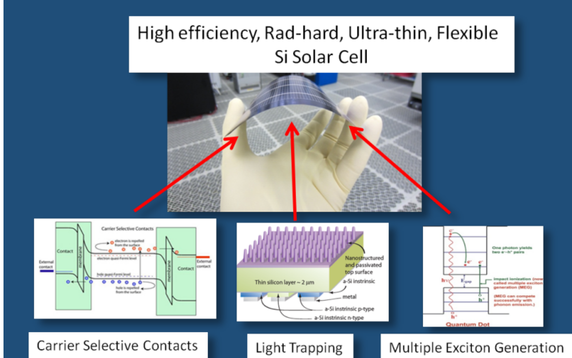
Applications

NASA

Advanced photovoltaic technologies are essential for improvements in the capacity and reliability of power generation systems in future space exploration missions. The new modeling and simulation tools for ultra-thin Si PV cell technologies, incorporating models for new physical mechanisms will help NASA to: a) assess technologies, devices, and materials for novel photovoltaic technologies; b) better evaluate the performance and radiation response at early design stage; and c) set requirements for hardening and testing; reduce the amount of testing cost and time.

Commercialization

Higher efficiency solar cells are needed to reduce solar array mass, volume, and cost in NASA space missions. In addition, low costs of manufacturing could allow these new solar cells to compete for terrestrial applications such as distributed power or grid power replacement/backup. Potential commercial applications will occur through the development of high performance (high W/kg, high W/m^2, and low \$/W) cells that could be used for terrestrial and space applications in both the military and commercial sectors. All satellites, military and commercial, suffer from solar cell degradation due to the effects of radiation. The higher efficiency and radiation hardness of the novel ultra-thin Si solar cells will reduce the weight of the solar array and maintain the power generation capacity of the spacecraft or satellite system.



Firm Contact

David Thomas
david.thomas@cfdrc.com
701 McMillian Way NW, Suite D
Huntsville, AL 35806-2923
(256) 726-4800

Proposal number: 14-1 Z1.01-9707

Spectrally Matched Wideband Metamaterial Emitters for High Power and Efficient Thermo-Photovoltaic Converters—Phase I

SensorMetrix

Abstract

A thermophotovoltaic (TPV) system is a promising energy conversion device that generates the electric power from short wave infrared (SWIR) thermal radiation. However, poor conversion efficiency restricts the usage of this technology in practical applications. One of the reasons for low efficiency is a poor match between thermal radiated power and TPV cell conversion band. The solution for resolving these issues is to utilize a metamaterial selective emitter whose thermal emission band is spectrally matched to the energy conversion band of the TPV cell. On one hand conventional emitters are broadband and poorly matched to TPV band gap. On the other hand, some natural frequency selective emitters (SE) only emit in a narrow frequency band, limiting the total power throughput of the TPV system. This proposal thus aims to experimentally investigate wideband metamaterial emitters, whose emission band is spectrally matched and utilizes the entire energy conversion band of the TPV cell.

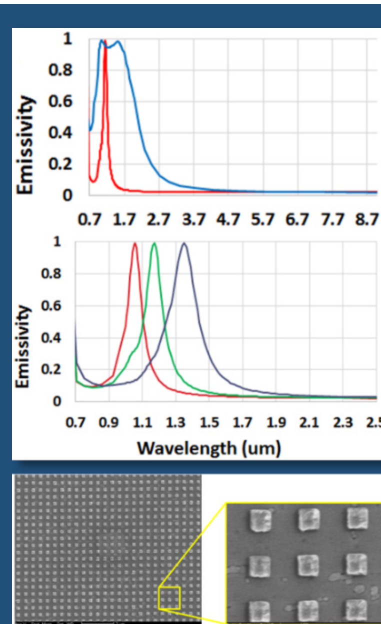
Applications

NASA

Radioisotope Power Systems (RPS) are the preferred technology for NASA deep space missions. The proposed technology offers significant improvement in both efficiency and mass specific power performance enabling for a variety of future NASA mission concepts. The technological gains in spectral efficiency will enable the metamaterial (MM)-TPV systems to be commercialized for future NASA deep space missions.

Commercialization

The technological gains in efficiency and power throughput as a result of this proposed research will enable the metamaterial (MM)-TPV systems to be commercialized in a wide range of applications, including concentrated solar power generation, and portable lightweight solid-state electrical power generators. A TPV-based generator will be competitive with ICE-based power generators in terms of overall fuel efficiency. The specific power range from few hundreds watts to few kilowatts is targeted. The technical discussion in this proposal details why a metamaterial selective emitter will offer sufficient overall efficiency gain to enable TPV systems to be competitive with internal combustion engine generators. Other attending performance advantages—quiet operation, no moving parts/low maintenance, ease of operation, size and weight—will enable TPV-based systems to penetrate the market.



Firm Contact

Anthony Floyd Starr
astarr@sensormetrix.com
8400 Juniper Creek Ln., St 102
San Diego, CA 92126-1074
(858) 653-5270

Proposal number: 14-1 S3.01-9440

High-Efficiency, Radiation-Hard, Lightweight IMM Solar Cells—Phase I

MicroLink Devices, Inc.

Abstract

Future NASA exploration missions require high specific power (>500 W/kg) solar arrays. To increase cell efficiency while reducing weight and maintaining structural integrity, we propose an approach to cell design that involves the use of quantum dots and epitaxial lift-off. In the near term, this approach will allow us to improve on what are currently the best space solar cells available in terms of efficiency and material properties for space utilization. In the proposed Phase I project, MicroLink and its collaborator, Rochester Institute of Technology, will incorporate InAs quantum dots (QDs) in the InGaAs subcell of an InGaP/GaAs/InGaAs triple-junction solar cell to increase radiation tolerance and efficiency, thereby improving end-of-life performance of the solar cell by >5%. By incorporating quantum dots into the InGaAs third cell, we will also extend the wavelength absorption range of InGaAs cell to beyond 1,250 nm, thereby increasing the current produced in the bottom subcell.

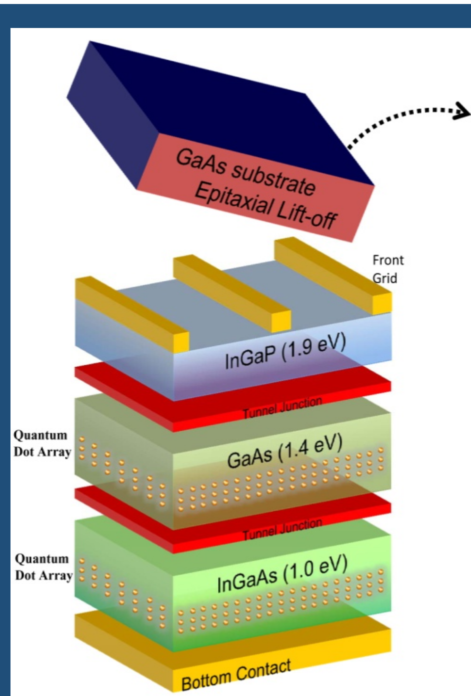
Applications

NASA

The improved radiation tolerance and temperature coefficients will open the design space for NASA-specific missions such as low-light-intensity missions to the Jupiter system or high-light-intensity missions near Mercury and the Sun. Solar panels made up of quantum-dot-embedded triple-junction epitaxial lift-off (ELO) solar cells are lighter than those containing conventional solar cells, and the high specific power will make them suitable for the requirements of solar electric propulsion (SEP) applications. Furthermore, cost reduction factors such as the substrate reuse achievable with ELO solar cells make them more attractive for applications that require a large number of panels.

Commercialization

Potential non-NASA applications include spacecraft, unmanned aerial vehicles (UAVs), and terrestrial energy collection. In spacecraft applications, the proposed cells are a suitable replacement for existing solar cells and will enable spacecraft power generation using higher specific power solar panels. The proposed cells are an enabling technology for large-scale solar electric propulsion (SEP) spacecraft. In UAV applications, the proposed cells can act as a supplement to battery power for endurance enhancement. High efficiency, lightweight cells this type are an enabling technology for high altitude, long endurance (HALE) UAVs such as DARPA Vulture. In terrestrial applications, the proposed cells can be used in solar sheets for generation of electricity for off-grid applications, e.g., military field deployments, civilian outdoors and camping, and supplementary power for mobile devices such as phones.



Firm Contact

Noren Pan
npan@mldevices.com
6457 West Howard Street
Niles, IL 60714-3301
(847) 588-3001, Extension: 13

Proposal number: 14-2 S3.01-9237

High Efficiency Direct Methane Solid Oxide Fuel Cell System—Phase II

Nexceris, LLC

Abstract

NASA has a defined need for energy dense and highly efficient energy storage and power delivery systems for future space missions. Compared to other fuel cell technologies, solid oxide fuel cell (SOFC) based systems are better suited to meeting NASA's efficiency targets while operating directly on methane and oxygen reactants. SOFC power systems for lunar landers and other exploration vehicles are an ideal application for this technology, as well as for power generation on the Moon or on Mars. Nexceris has established SOFC technology that offers high power density with direct internal fuel reforming and high single-pass fuel utilization, making it uniquely suited for achieving NASA's performance and efficiency requirements. In this project, Nexceris will establish a process model for an SOFC system that operates with oxygen and methane reactants, build a three-dimensional CAD model of the methane/oxygen SOFC system, build and test 1-kW scale SOFC stacks under application-specific conditions, demonstrate 70 percent electrical efficiency in a stack with only methane and oxygen reactant feeds, and evaluate long term durability and thermal cycling capability of the stack.

Applications

NASA

Solid oxide fuel cells have promise to meet some of NASA's emerging power generation system needs. An SOFC power system using the same reactants as the propulsion system (cryogenically stored oxygen and methane) can provide exceptional energy density. Lunar landers or other exploration vehicles are an ideal application of this technology. SOFC systems also may find uses on the Moon or on Mars for generating power from hydrocarbons produced from In-Situ Resource Utilization technologies.

Commercialization

The lightweight and high efficiency SOFC technology to be developed on this project is specifically geared toward meeting the demanding requirements of NASA applications, but will have near-term applicability to energy systems for unmanned underwater vehicles. Meeting the robustness requirements (i.e., thermal cycles and rapid start-up) for NASA applications will make Nexceris' SOFC technology suited for other military applications, such as gen-sets, auxiliary power units for silent-watch vehicles, and unmanned aerial vehicles. Additionally, the internal reforming stack technology to be developed in this SBIR project is directly applicable to residential micro-combined heat and power systems.

Firm Contact

Scott L. Swartz, Ph.D.
s.swartz@nexceris.com
Nexceris, LLC
404 Enterprise Drive
Lewis Center, OH 43035-9423
(614) 842-6606, Extension: 103

Proposal number: 14-2 H8.01-8950

Li Metal Protection for High Energy Space Batteries—Phase II

NOHMs Technologies

Abstract

NOHMs Technologies proposes to develop a novel ionic liquid electrolyte formulation developed for the Lithium-Sulfur chemistry that can protect the lithium metal and has demonstrated superior performance and safety characteristics with the potential to offer 600 Wh/kg on the cell level. For this NASA Phase I project, NOHMs Technologies will optimize our proprietary ionic liquid electrolyte and demonstrate how the electrolyte provides safe, non-flammable high-energy performance and provides Li-metal protection. NOHMs will provide full cell data and analysis to demonstrate the feasibility of our system to meet NASA's 'Far Term Mission' specific energy and energy density goals.

Applications

NASA

Advanced batteries are required for future space missions. These uses include batteries for astronaut equipment and EVA suits, crew exploration vehicles, in-space habitats, surface habitats, humanoid robots, landers, ISRU, ISS astronaut equipment, life support systems, and photovoltaic energy storage. Science Mission Directive missions include planetary probes, landers, rovers, and orbiters, all which require high energy, safe batteries.

Commercialization

This project can provide an opportunity for the widespread adoption of high energy, safe Lithium-Sulfur (Li-S) batteries in the consumer, automotive vehicles and grid energy storage market. Mobile consumer devices require faster performance and smaller sizes for greater portability. The principal limitations for these mobile devices, battery size and weight, are functions of energy density, and the basic chemistry of lithium-ion batteries for these devices has not changed in a decade. NOHMs lithium-sulfur batteries represent a 3x improvement over the state-of-the-art and 33% improvement over next-generation lithium-ion batteries, an attractive value proposition for the company's partners and prospective customers.

Firm Contact

Shivaun Archer
shivaun@nohms.com
1200 Ridgeway Ave, Suite 110
Rochester, NY 14615-3714
(607) 227-5464

Proposal number: 14-2 Z1.02-9938

Solid State Large Area Pulsed Solar Simulator for 3-, 4- and 6-Junction Solar Cell Arrays—Phase II

Angstrom Designs, Inc.

Abstract

The ssLAPSS expands on the SOP LAPSS by upgrading the light sources to enable future solar cell technologies while maintaining all of the current, proven calibration and test methods. The ssLAPSS enables testing of current SOP 3-junction cells and also upcoming 4- and 6-junction solar cells. The ssLAPSS uses planar arrays of 6 different wavelength LEDs located in close proximity to the string under test in the solar array. The individual LED intensity control gives great flexibility to meet power and spatial uniformity requirements.

The LED sources are selected to each illuminate one junction in a 6-junction cell. The same LEDs will also be used for 3- and 4-junction cells. This means that one ssLAPSS can measure the current (3-junction) and future (4- and 6-junction) cells. This technology is also highly flexible so that cells with an even greater number of junctions or cells with different spectral divisions could be measure by producing a ssLAPSS with a greater number of LEDs or a different spectral mix of LEDs in the illumination array.

Four- and 6- junction LAPSS technology is necessary to evaluate, test and fly advanced solar cell technologies. The ssLAPSS extends an essential, proven measurement method to the future of space power conversion technologies.

Applications

NASA

The LAPSS is critical to the study of solar cell performance at the string and array level. NASA can use the ssLAPSS to measure solar array performance on current and future solar arrays. Because of this need, it is very likely that other labs at NASA beyond GRC would benefit from ssLAPSS capability as well, including:

- LAPSS testing of 3-, 4- & 6-junction solar cells, strings and arrays
- LILT and deep space testing
- On spacecraft and on rocket remote testing
- Solar cell science, including spectral sensitivity measurements
- High voltage (>300V) and long string measurements

Commercialization

The potential non-NASA applications are any organization that currently uses a LAPSS and plans to fly state of the art solar cells in the future. This includes the Department of Defense, other US government labs, foreign government programs and commercial sector companies. All have an interest in LAPSS for 3-, 4- and 6-junctions.

Firm Contact

Tim Halsey
tim.halsey@angstromdesigns.com
PO Box 2032
Santa Barbara, CA 93120-2032
(805) 284-4535

Proposal number: 14-1 S3.01-9098

Titanium-Water Heat Pipe Radiator for Spacecraft Fission Power—Phase II

Advanced Cooling Technologies, Inc.

Abstract

The proposed program will develop titanium/water heat pipes suitable for Spacecraft Fission Power. NASA is examining small fission power reactors for future space applications with the most recent being Kilopower, which provides roughly 1 kW of electric power. Advanced Cooling Technologies, Inc. (ACT) will develop hybrid grooved/screen wick heat pipes. Hybrid wick heat pipes will satisfy the Kilopower requirements and ACT has already successfully tested similar hybrid wick heat pipes. The overall technical objective of the Phase I and Phase II projects is to develop a titanium/water heat pipe radiator suitable for Spacecraft Fission Power, such as Kilopower. During Phase II, ACT is investigating a hybrid wick system, utilizing a screened evaporator and grooved condenser design. The heat pipe design will also include a small NCG charge, which allows the fluid in the heat pipe to freeze in a controlled fashion as the heat pipe is shut down, avoiding damage, and aids with start-up from a frozen condition. In addition to testing the heat pipes in different orientations, freeze/thaw tolerance will also be demonstrated.

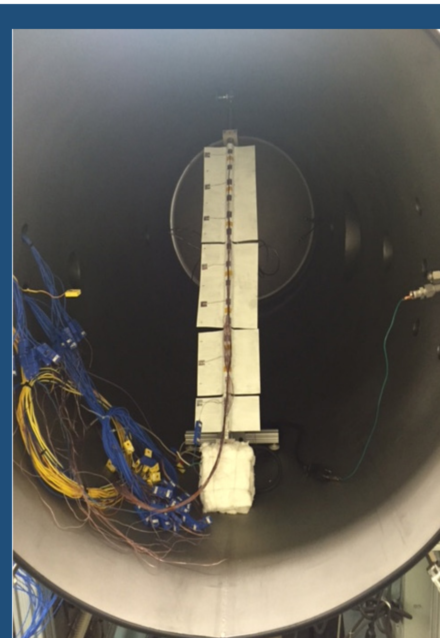
Applications

NASA

The immediate NASA application is for space fission nuclear reactors that utilize Stirling converters or thermoelectrics for power conversion. Radioisotope Power Systems (RPSs) operate below 1 kWe while the Fission Surface Power (FSP) systems have a designed operable range from 10 to 100 kWe. A Kilopower system design addresses the gap between the RPS and FSP systems with a designed operable range of 1 to 10 kWe. The Kilopower nuclear reactor supplies heat energy to Brayton or Stirling convertors to produce electricity and hybrid titanium/water heat pipes transport the waste heat to radiators where it is rejected to the environment.

Commercialization

There is a commercial application for high temperature heat pipes in satellite thermal control. Future power amplifiers for satellite communication will involve highly integrated electronics. This high density electronics packaging leads to substantial improvement in performance per unit mass, volume and power. Aluminum/ ammonia constant conductance heat pipes have been a proven technology for spacecraft thermal control. Unfortunately, ammonia only works up to about 80 °C, while the use of high-temperature electronics such as the next generation of power amplifiers for satellites communications requires operation up to 150 °C. This allows a significant reduction in the radiator size and mass, since radiation heat transfer scales with T^4. A high temperature titanium-water heat pipe is required to minimize the resultant temperature drop such that the radiator size will further decrease, since the required thermal radiator panel size will be reduced at higher rejection temperature. The titanium-water heat pipes can operate successfully over the temperature range of 25 to 280 °C.



Firm Contact

William Anderson
Bill.Anderson@1-act.com
1046 New Holland Avenue
Lancaster, PA 17601-5688
(717) 295-6104

Proposal number: 14-2 H8.02-9974